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Patent Application En of

A Method and system the
Device and process for generation of a
partly synthesized high-quality signal for
acceleration of an armature of an electric drive

by Andreas Boehringer

Title page



Field
of
the
invention
(attached)

page
break

These types of
accelerometers
have certain
deficiencies
though.

Background of the Invention

In order to design high-quality position or speed control for a rotary or linear electric drive it has been customary in the past to control the components directly generating torque or force in the innermost loop, that is, in cascade control [1;2]. The most recent developments [3;4] have shown that on the other hand it is highly advantageous not to control the torque or force generating components of the current volume indicators indirectly, but to guide the acceleration of the part propelled, that is, in cascade control. In the case of rotary drives this is the spin of the rotor, and in the case of linear drives, the linear acceleration of the armature. Hence use of an accelerometer is required for registration of these values. for example, an accelerometer which operates on the Ferraris principle [3;4;5]. One type of that may be used, For one thing, however, this type of accelerometer, on the whole, is characterized by a delay in measurement, albeit a small one. For another, this accelerometer can never be completely rigidly connected to the place engaged by rotary thrust in the case of a rotary drive, or by linear thrust in the case of a linear drive. The result of these two facts is that loop limit cycles and/or self-excited oscillations are formed in the cascade control loop for the acceleration, [4]. Unless these limit cycles and/or self-excited oscillations are prevented, use of such a cascade control loop is not successful for high-quality position or speed control. A process for suppression of these limit cycles and/or self-excited oscillations in the cascade control loop for acceleration has been proposed for rotary drives [4]. However, this process has the disadvantage that its application is.

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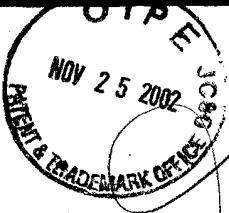
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Field of The Invention



The invention relates to a method and system for controlling rotary or linear electric drives. More particularly, the invention relates to a system and method for ~~a pa~~ the generation of a partly synthesized signal of high dynamic quality to control the acceleration of an armature (rotary or linear) of an electric drive. -

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* 2-
It is therefore an object of the invention

Thus, a need exists for a low cost cascade system and method for controlling the acceleration of an armature of an electric drive that is less insensitive to flux drive fluctuations, and prevents limit cycles and self-excited oscillations in the cascade acceleration control loop. -

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insert attached *²⁻¹

replace b_m for b_m

replace m for m

" x for x

" z for z

Universal change:

$F_T(p)$ for $FT(p)$

$F_H(p)$ " $FH(p)$

$F_g(p)$ " $Fg(p)$

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b_{EM} " bEM

extremely costly and " in addition that it reacts with extreme sensitivity to fluctuations in the parameters of the drive.

~~This is therefore the object of the invention~~

Summary of the Invention

~~A partly synthesized signal of high dynamic quality for acceleration of an armature of an electric drive can be generated by means of the device claimed for the invention as proposed here. Cascade control of acceleration can be achieved by means of this signal, to a great extent independently of the parameters of the drive, while limit cycles and/or self-excited oscillations are prevented in this cascade acceleration control loop.~~

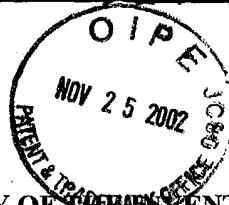
Brief Description of the Drawings

~~A partly synthesized signal of high dynamic quality can be generated with a device as described in Claims 1-12.~~

Detailed Description of the Preferred Embodiments

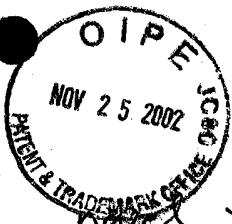
For the purpose of generating a high-quality signal for acceleration of an electric drive, first the acceleration signal, $b_m = \alpha \cdot F_g(p)$, (in which $F_g(p)$ describes the measurement transfer function), is registered and then the torque m or the propulsive force f as substitute acceleration signal $b_{EM} = m$ or $b_{EM} = f$, and, in scaling the acceleration signal b_{EM} , all losses arising throughout propulsion being disregarded and conversion is adopted being that of an absolutely rigid connection of the surface engaged by the thrust of the drive to the place at which the effect used for registration of acceleration is used. The result is scaled so that the relation $b_m = \alpha \cdot F_g(p) = b_{EM} \cdot F_g(p)$ is satisfied. The acceleration signal $b_m = \alpha \cdot F_g(p)$, is taken to a low-pass filter with the low-pass transfer function $FT(p)$; hence the signal $x = b_m \cdot FT(p)$ is present at the output of the filter. and the substitute acceleration signal becomes a high-pass filter with the high-pass transfer function $FH(p)$, which satisfies the relationship of $FH(p) = FT(0) - FT(p)$. $FH(p)$ is adjacent to the output of which is the signal $y = b_{EM} = \alpha \cdot F_g(p)$. y is formed; it is used as a substitute signal of high

~~$x + y$~~ Lastly, the synthesized signal $x + y$ is formed; it is used as a substitute signal of high



SUMMARY OF INVENTION

It is therefore an object of the invention to provide a system and method for controlling the acceleration of an armature of an electric drive by generating a high quality acceleration error correction signal \underline{z} , the system comprising an accelerometer for obtaining a measured armature acceleration value \underline{b}_m , which is equal to the product of a true armature acceleration α , and an acceleration measurement transfer function $F_g(p)$, and means for obtaining a measured acceleration signal, \underline{b}_{Em} , which is generated from a measured substitute acceleration signal \underline{b}_E . \underline{b}_m and \underline{b}_{Em} are scaled such that the relationship of $\underline{b}_m = \alpha \cdot F_g(p) = \underline{b}_{Em} \cdot F_g(p)$ is satisfied. The measured armature acceleration signal \underline{b}_m is filtered with a first filter transfer function of $F_T(p)$, and the measured acceleration signal \underline{b}_{Em} is filtered with a second filter transfer function of $F_H(p)$. The first and second filter outputs are combined to form the partly synthesized high quality acceleration error correction signal $\underline{z} = \underline{b}_m \cdot F_T(p) + \underline{b}_{Em} \cdot F_H(p)$.



The features and advantages
of the present invention will best be
understood by reference to the detailed
description of the preferred embodiment
which follows, when read in conjunction
with the following drawings, in which:

Fig. 1 illustrates a control system
for a plurality of electric drive types,
in accordance with an embodiment of the
invention;

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Fig. 2 illustrates a first alternative
control system
embodiment for a plurality of electric
drive types, in accordance with a first
alternative embodiment of the invention;

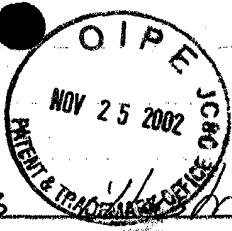


Fig. 3 illustrates a control system
for a plurality of electric drive types,
in accordance with a ~~first~~^{third} alternative
embodiment of the invention; and
Fig. 4 illustrates a control system
for a plurality of electric drive types,
in accordance with a ~~first~~^{third} alternative
embodiment of the invention -

*²⁻³

The various features of the
preferred embodiments will now be described
with reference to the drawings, in which
like parts are identified with the same
reference characters. The following
description of the presently contemplated
best mode of practicing the invention
is not to be taken in a limiting sense,
but is provided merely for the purpose
of describing the general principles of
the invention.

dynamic quality for the instantaneous armature acceleration value in automatic control of the drive.

For this purpose, in the case of rotary current propulsion, the rotary acceleration α of the rotated armature is registered metrologically by an accelerometer ³⁰ connected to ~~this~~ the armature and preferably operating on the Ferraris principle, and is consequently available as measured acceleration signal $b_m = \alpha$ - $F_g(p)$. $F_g(p)$, with $F_g(0) = 1$, here represents the so-called measurement transfer function of the accelerometer. The torque m of the ^{electric} ²⁰ drive, hereafter designated as substitute acceleration signal $b_E = m$, is also registered ^{measured} metrologically and accordingly is available as measured substitute acceleration signal $b_E = m$. As is to be immediately perceived, use may of course be made, without impairing the operation of the device claimed for the invention, in place of the torque m of the drive, ~~also directly~~ of the torque-forming transverse-current components i_q of the current volume indicator of the rotary current fed winding of the drive as substitute acceleration signal $b_E = i_q$. In what follows, as is customary in ^{control engineering} metrology, it is assumed that ~~on the~~ ^{with} both one-hand the measured acceleration signal b_m , and on the other the measured substitute acceleration signal b_{Em} , all losses occurring in the drive in question being disregarded, and a mechanically absolutely rigid connection of the surface of the armature rotated engaged by the torque to the position of the rotated part of the rotary acceleration meter, at which the effect used for registration of acceleration is generated being taken as a basis, is each scaled so that the relation $b_m = \alpha \cdot F_g(p) = b_{Em} \cdot F_g(p)$ is satisfied. The measured acceleration signal b_m is delivered to the input of a low-pass filter with the low-pass transfer function $FT(p)$, $FT(0)$ preferably equaling 1. Hence the signal $x = b_m \cdot FT(p)$ can be received at the output of the low-pass

where
with

filter. The measured substitute acceleration signal bEm is delivered to the input of a high-pass filter with high-pass transfer function $FH(p) = FT(0) - FT(p) + Fg(p)$. Consequently, the signal $y = bEm \cdot [FT(0) - FT(p) + Fg(p)]$ may be received at this high-pass filter. A signal $z = bm + FT(p) + bEm \cdot [FT(0) - FT(p) + Fg(p)]$ is now formed in accordance with the relation $z = x + y$. This synthesized signal is subsequently used as a very high-quality dynamic substitute as the undelayed instantaneous value of the rotary acceleration α of the rotated armature in automatic control of the drive in question.

In the case of a traveling-wave drive, the linear acceleration α of an armature in linear movement is ~~metrologically registered~~ measured by means of an accelerometer mechanically connected to this armature, one preferably operated on the Ferraris principle transposed to linear movement, and is accordingly available as measured acceleration signal $bm = \alpha \cdot Fg(p)$. In this instance $Fg(p)$, with $Fg(0) = 1$, represents the so-called measurement transfer function of the accelerometer. The linear force f of the drive, to be designated in what follows as substitute acceleration signal $bE = f$, is also ~~registered~~ measured and is accordingly available as measured substitute acceleration signal bEm . As is to be immediately perceived, without impairing the operation of the device claimed for the invention, the transverse-current component iq immediately forming the linear force of the current volume indicator of the multiphase current-fed winding of the drive may be used as substitute acceleration signal $bE = iq$. It is assumed in what follows, as is customary in control engineering, that both the measured acceleration signal bm and the substitute acceleration signal bEm , all losses occurring in the drive in question being disregarded and a mechanically absolutely rigid

connection of the surface of the armature rotated engaged by the torque to the position of the rotated part of the rotary acceleration meter at which the effect used for registration of acceleration is generated being taken as a basis, is each scaled so that the relation $b_m = \alpha \cdot F_g(p) = b_{Em} \cdot F_g(p)$ is satisfied.

¶ The measured acceleration signal b_m is delivered to the input of a low-pass filter with the low-pass transfer function $FT(p)$, where ^{with} $FT(0)$ preferably equaling 1. Hence the signal $x = b_m \cdot FT(p)$ can be received at the output of the low-pass filter. The measured substitute acceleration signal b_{Em} is delivered to the input of a high-pass filter with high-pass transfer function $FH(p) = FT(0) - FT(p) \cdot F_g(p)$. Consequently, the signal $y = b_{Em} [FT(0) - FT(p) \cdot F_g(p)]$ may be received at the output of this high-pass filter. A signal $z = b_m \cdot FT(p) + b_{Em} = [FT(0) - FT(p) \cdot F_g(p)]$ is now formed in accordance with the relation $z = x + y$. This synthesized signal is subsequently used as a very high-quality dynamic substitute for the undelayed instantaneous value of rotary acceleration α of the rotated armature in automatic control of the drive in question.

In the case of direct-current propulsion the rotary acceleration α of the rotated armature is registered ^{measured} metrologically by an accelerometer ~~134,5~~ connected to this armature and preferably operating on the Ferraris principle, and is consequently available as measured acceleration signal $b_m = \alpha \cdot F_g(p)$. $F_g(p)$, with $F_g(0) = 1$, here represents the so-called measurement transfer function of the accelerometer. The torque m of the drive, hereafter designated as substitute acceleration signal $b_E = m$, is also registered ^{measured} metrologically and accordingly is available as measured substitute acceleration signal b_{Em} . As is to be perceived immediately, use may of course be made, ^{directly} without impairing the operation of the device claimed for the

invention, in place of the torque m of the drive, also directly of the armature current i_a of the direct-current fed winding of the drive as substitute acceleration signal $b_E = i_a$. In what follows, as is customary in metrology, it is assumed that ~~on the control engineering both~~ the measured acceleration signal b_m and ~~on the other~~ the measured substitute acceleration signal b_{Em} , all losses occurring in the drive in question ~~are~~ being disregarded and a mechanically absolutely rigid connection of the surface of the armature rotated engaged by the torque to the position of the rotated part of the rotary acceleration meter at which the effect used for registration of acceleration is generated being taken as a basis, is each scaled so that the relation $b_m = \alpha \cdot F_g(p) = b_{Em} \cdot F_g(p)$ is satisfied. The measured acceleration signal b_m is delivered to the input of a low-pass filter with the low-pass transfer function $FT(p)$, $FT(0)$ preferably equaling 1. Hence the signal $x = b_m \cdot FT(p)$ can be received at the output of the low-pass filter. The measured substitute acceleration signal b_{Em} is delivered to the input of a high-pass filter with high-pass transfer function $FH(p) = FT(0) - FT(p) \cdot F_g(p)$. Consequently, the signal $y = b_{Em} \cdot [FT(0) - FT(p) \cdot F_g(p)]$ may be received at the output of this high-pass filter. A signal $z = b_m \cdot FT(p) + b_{Em} \cdot [FT(0) - FT(p) \cdot F_g(p)]$ is now formed in accordance with the relation $z = x + y$. This synthesized signal is subsequently used as a very high-quality dynamic substitute as the undelayed instantaneous value of the rotary acceleration α of the rotated armature in automatic control of the drive in question.

The device and the process for obtaining a partly synthesized signal of high dynamic value for acceleration of the armature of a machine is explained in detail in what follows on the basis of an example of a separately excited direct-current machine and with reference to the drawings in Figures 1 to 4.

in the ^a
It is advantageous ~~for~~ design of high-quality position or speed control ~~for~~ a separately excited direct-current machine to control rotary acceleration of the armature rather than the armature current in the innermost loop. For this purpose, the ^{measured} rotary acceleration α of the rotor is registered by an accelerometer, preferably one operating on the Ferraris principle, and is accordingly available as measured rotary acceleration $b_m = \alpha \cdot F_g(p)$. Block 1 (see Figures 1, 2, 3, and 4) with transfer function $F_g(p)$, with $F_g(0) = 1$, describes the so-called measurement frequency response of the accelerometer.⁵⁰ The torque m of the drive, which in what follows is designated as substitute acceleration signal $b_E = m$, is also registered ^{measured} metrologically and accordingly is available as measured substitute acceleration signal b_{Em} . Armature current I_a of the direct-current-fed armature winding of the drive may, of course, also be used as substitute acceleration signal $b_E = I_a$ in place of the moment m of the drive. In what follows, as is customary in control engineering, it is assumed that ~~on the one hand~~ the measured acceleration signal b_m and ~~on the other~~ the measured substitute acceleration signal b_{Em} , all losses occurring in the drive in question ^{are} disregarded and a mechanically absolutely rigid connection of the surface of the armature rotated engaged by the torque to the position of the rotated part of the rotary acceleration meter at which the effect used for registration of acceleration is generated being taken as a basis, is each scaled so that the relation $b_m = \alpha \cdot F_g(p) = b_{Em} \cdot F_g(p)$ is satisfied.

④ The measured acceleration signal b_m is delivered to the input of a low-pass filter 2 (see Figures 1, 2, 3, and 4) with the low-pass transfer function $FT(p)$, ^{with} $FT(0)$ preferably equaling 1. Hence the signal $x = b_m \cdot FT(p)$ can be received at the output of the low-pass filter.² The measured substitute acceleration signal b_m is delivered to the input of a high-pass filter 3 (see Figures 1 and

2) with high-pass transfer function $FH(p) = FT(0) - FT(p) \cdot Fg(p)$. Consequently, the signal $y = bEm + [FT(0) - FT(p) - Fg(p)]$ may be received at this high-pass filter.³ A signal $z = bm$ $[FT(0) - FT(p) + Fg(p)]$ is now formed in accordance with the relation $z = x + y$. This synthesized signal is subsequently used as a very high-quality dynamic substitute as the undelayed instantaneous value of the rotary acceleration α of the rotated armature in automatic control of the drive in ~~as well~~ question. The difference between the set value α_{sett} assigned by a superimposed control system and the synthesized signal z is delivered to a suitable control unit 4 as control difference (see Figure 1). Delay of the measurement transfer function $Fg(p)$ and the considerable disturbance of the transfer function $FM(p)$ are eliminated from the control frequency response, which is of decisive importance for stability, possible limiting cycles, and self-excited oscillations. The last-named transfer function, $FM(p)$, describes the mechanical frequency response between the surface of the armature moved which is engaged by the thrust of the drive and the position of the moved part of the accelerometer at which the effect used for registration of acceleration is generated. The low-pass filter with low-pass transfer function $Fy(p)$ almost entirely eliminates the influence of this mechanical frequency response. So long as transfer function $FM(p)$ does not deviate significantly from value 1, damping of the low-pass filter does not exhibit significant values. But, starting with the limit frequency of the low-pass filter, the damping rises sharply, so that the unavoidable resonance step-ups of the mechanical frequency response virtually exert no more influence. The delay of the acceleration signal bm by the measurement transfer function $Fg(p)$ and the delay additionally caused by the low-pass filter are entirely eliminated by signal $y = bEm + FH(p)$ at the output of the high-pass filter in the frequency response

in question of the control loop formed by means of the synthesized signal z .

~~system and method of~~

~~is further described~~

The ~~procedure claimed for the invention as presented is also~~ balance of elements shown described by the block diagram in Figure 1. The first-order delay element 5 (see Figures, 1, 2, 3, and 4) with amplification V_R and time constant T_E describes the delayed reaction of the armature current i_a to change in voltage at the input of the delay element. $*^9$

\downarrow from
3000's
vert
Fig. 2

T_E

\downarrow In Fig. 2,

In a preferred embodiment, the output voltage of the pulse inverter which feeds the armature winding of the drive is derived directly from a two-point control loop \downarrow , on the principle of the discrete-time switching condition control with a clock frequency $f_A = 1/TA$ in the 100-kHz range. Consequently, in Figure 2, the controller 4 is replaced by the two-point element 6, a scanning element 7 with scanning frequency $f_A = 1/TA$, and a zero-order holding element 8. Amplifications V and $-V$ in the two-point element 6 take the ratio of converter output voltage to rated voltage of the machine into account. The scanning element 7 and the zero-order holding element 8 allow for the effect of discrete-time switching condition control. In this embodiment of the device, claimed for the invention, the limit frequency selected for the low-pass filter 2 with low-pass transfer function $FT(p)$ is to be low enough that no self-excited oscillations occur in the two-point control circuit for synthesized signal z .

it occur, as it frequently does,
Should the circumstance frequently occurring in practical application that the connection between the measured substitute acceleration signal b_{EM} and the measured acceleration signal a_m is only incompletely described by the equation $a_m = F_g(p) * b_{EM}$ prove to be a source of disturbance for the quality of the two-

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system and method

point cascade control, the process claimed for the invention is expanded. This expansion is characterized by the block diagram shown in Figure 3. In this instance, the transfer function $FM(p) \circ F_m(p)$ describes the mechanical frequency response from the surface of the armature set in movement (which is engaged by the thrust of the electrical motor) and which is positioned between the drive to the position of the part of the accelerometer set in movement at which the effect used for registration of acceleration. acceleration is generated. The relationship between the substitute acceleration signal b_{EM} and the measured acceleration α_m is accordingly expressed as $\alpha_m = FM(p) \circ F_g(p) \circ b_{EM}$. This mechanical frequency response with transfer function $FM(p)$ (see Figures 3 and 4) is now taken into account in that the high-pass filter 3 with high-pass transfer function $F_H(p) = FT(0) - FT(p) \circ F_g(p)$ is replaced by a modified high-pass filter 10 with modified high-pass transfer function $F_H(p) = FT(0) - FT(p) \circ F_g(p) \circ FM(p)$. It is advisable in this process not to determine the limit frequency of the low-pass filter 2 with low-pass transfer function $FT(p)$ until the high-pass filter 3 with high-pass transfer function $F_H(p)$ has been replaced by modified high-pass filter 10 with modified high-pass transfer function $F_H(p)$.

Should the transfer function $FM(p)$ have a plurality of polar and/or zero positions, development of the high-pass filter 10 with modified high-pass transfer function $F_H(p)$ is found to be very costly. In order to reduce this cost in development of this high-pass filter 10, the process claimed for the invention may be further modified as described in the following. A part

shown in Fig. 4,

$$F_0(p) = \frac{(1+p \cdot T_u) \cdot (1+2 \cdot D_v \cdot p \cdot T_v + p^2 \cdot T_v^2) \dots}{(1+p \cdot T_i) \cdot (1+2 \cdot D_j \cdot p \cdot T_j + p^2 \cdot T_j^2) \dots}$$

* 10^{-4} (new ft)

is separated from the transfer function of the mechanical frequency response. This part allows for one or more poles

*104 Fig. 4 illustrates a control system
for a plurality of electric drive types
alternative
in accordance with a third embodiment
of the invention. In fig. 4, the transfer
of the mechanical frequency response
function $F_m(p)$ of Fig. 3 has been
separated into two components, $F_{m, \text{RES}}(p)$
and $F_o(p)$. $F_o(p)$ is defined as follows:

and/or zero positions with particularly high values of $T\mu$, Tv , Ti , or Tj . The transfer function of the mechanical frequency response may be described as follows

$$F_M(p) = F_0(p) \cdot F_{M,\text{Rest}}(p) \quad \text{with} \quad F_{M,\text{Rest}}(p) = F_M(p) \cdot F_0^{-1}(p).$$

The mechanical frequency response with transfer function $F_M(p)$ is now taken into account only in approximation by the circumstance that the high-pass filter 3, with high-pass transfer function $FH(p) = FT(0) - FT(p) \cdot Fg(p)$ is replaced by a modified high-pass filter 11 with modified high-pass transfer function $Fh^*(p) = FT(0) - FT(p) \cdot F_{11}(p) \cdot F_0(p)$. It is advisable not to determine the limit frequency of the low-pass filter 2 with low-pass transfer function $FT(p)$ in this process until the high-pass filter 3 with high-pass transfer function $FH(p)$ has been replaced by modified high-pass filter 11 with modified high-pass transfer function $Fh^*(p)$. The proposed process claimed for the invention is described by the block diagram in Figure 4.

* "attached."

Abstract

Add attached.

*"

The present invention has been described w/reference to certain exemplary embodiments thereof. However, it will be readily apparent to those skilled in the art that it is possible to embody the invention in specific forms other than those of the exemplary embodiments described above. This may be done without departing from the spirit and scope of the invention. The exemplary embodiments are merely illustrative and should not be considered restrictive in any way. The scope of the invention is defined by the appended claims and their equivalents, rather than the preceding description. -

[A system and method for the generation of a partly synthesized high-quality signal for acceleration of an armature of an electric drive]

ABSTRACT

A system and method for controlling the acceleration of an armature of an electric drive by generating a high quality acceleration error correction signal \underline{z} , the system comprising an accelerometer for obtaining a measured armature acceleration value \underline{b}_m , which is equal to the product of a true armature acceleration α , and an acceleration measurement transfer function $F_g(p)$, and means for obtaining a measured acceleration signal, \underline{b}_{Em} , which is generated from a measured substitute acceleration signal \underline{b}_E . \underline{b}_m and \underline{b}_{Em} are scaled such that the relationship of $\underline{b}_m = \alpha \cdot F_g(p) = \underline{b}_{Em} \cdot F_g(p)$ is satisfied. The measured armature acceleration signal \underline{b}_m is filtered with a first filter transfer function of $F_T(p)$, and the measured acceleration signal \underline{b}_{Em} is filtered with a second filter transfer function of $F_H(p)$. The first and second filter outputs are combined to form the partly synthesized high quality acceleration error correction signal $\underline{z} = \underline{b}_m \cdot F_T(p) + \underline{b}_{Em} \cdot F_H(p)$.